than that it is purely physiological and adaptive, and leads to a distinct gain of surface and a consequent increase in the efficiency of each and every corpuscle in performing its function, that for such a cause has assumed the discoidal form. That such a double vortical flux must take place from two opposite poles of a primitively globular or embryonic red blood-corpuscle in passing from its primitive globular to that of its completed or adult elliptical or discoidal form is self-evident upon mere contemplation of the geometrical conditions that must on *à priori* grounds accompany the transformation of a semifluid globular mass to the form of a disk with rounded edges. If such a vortical flux of its substance were maintained by every corpuscle during its double cycle of wanderings through the systemic and pulmonary circulations and throughout life, its efficiency in the processes of metabolism must necessarily be greatly increased. The fact that Amœba cannot move without developing a vortical flux of its own substance through itself, is, it seems to me, evidence of the possibility and probability of the same thing occurring in red blood-corpuscles. If the foregoing hypothesis is true with respect to red blood-corpuscles, we have no less than ten millions of vortex rings of particles whirling together in pairs for every cubic millimeter of blood that circulates through the vessels of our bodies.

A Study of the Transformations and Anatomy of Lagoa crispata, a Bombycine Moth.

By Alpheus S. Packard.

The larva of this moth is exceptional among caterpillars, for it has the rudiments of two pairs of abdominal legs more than the five pairs common to all other known Lepidoptera. It is also remarkable for its metameric glandular abdominal processes.

A very full and careful account of the life-history of this interesting moth has been published by Dr. J. A. Lintner, in his *Entomological Contributions*, No. ii, p. 139. He describes six stages, and gives an interesting account of the cocoon and mode of pupation.*

* See also two brief articles by myself: "On the Larva of Lagoa, a Bombycine Caterpillar with Seven Pairs of Abdominal Legs; with Notes on its Metameric Glandular Abdominal Processes." *Zoologischer Anzeiger*, 27. Juni, 1892, pp. 229-234; "The Bombycine Genus Lagoa, Type of a New Family," *Psyche*, July, 1892, pp. 281, 282.

The eggs were kindly sent me by Miss Emily L. Morton from New Windsor, N. Y., and received July 2, hatching in Brunswick, Me., July 3.

Egg.—Length, about 1.5–1.8; breadth, about 0.5 mm. The shell is very thin, membranous, and entirely transparent, and under a $\frac{1}{2}$-in. objective is seen to be structureless, showing no traces of polygonal areas.

They are similar to but not nearly so flat as those of *Phobetron pithecium*. They are laid in small irregular patches side by side in two rows, and are densely covered with white woolly hairs from the body of the moth. They are at first pale green, becoming yellowish as the embryo becomes mature and nearly ready to hatch.

Larva Stage I, Freshly Hatched.—Length, 1.5–1.8 mm. When first hatched they eat little holes in the upper surface of oak leaves. They have a thin soft skin; are flat oval, lying on one side, and at first are yellow. Body short and thick, rather broad, yet somewhat cylindrical, with eleven pairs of large dorsal tubercles, which are square at the tip, and give rise to very long white hairs of unequal size, some of which are nearly twice as long as the body. Besides the white hairs there are also short erect setæ, dark brown at the attenuated ends, which also arise from the large long subdorsal, not lateral, tubercles. The body, including the head, is pale straw-yellow.

It molted July 10–11, the length of the stage being from six to seven days. In this stage the head is not covered by the prothoracic segment, which though large has not yet become hoodlike. The very long fine spinulated hairs arise from all the tubercles, of which there are six on each segment, the dorsal tubercles on the second thoracic segment being slightly larger than those on any of the succeeding segments; the hairs in question are more abundant on the anterior segments, *i. e.* the second and third thoracic, and the five basal segments, than on those behind. From the dorsal and subdorsal tubercles arise about a dozen spine-like setæ, which are slender and about half as long as the body is thick; the end is acute, dusky, and thus made conspicuous in the mass of white delicate spinulated hairs clothing the body. None of these are poisonous. Stinging setæ arise from the minute infraspiracular tubercles. The spiracles are very minute and difficult to detect. On each of the abdominal legs, situated above the planta, is a pair of short clavate setæ, the seventh pair only bearing a single seta.

Fig. 1 represents the freshly hatched larva, Stage I, drawn with the tubercles, hairs and spines; *abl*[1], the first, *abl*[6], the sixth, pair of abdominal legs.

Fig. 2 represents the armature in Stage I; *a*, part of an ordinary finely spinulated hair; *b*, one of the smaller spinulated hairs situated on the head, and also on the tenth abdominal segment; *c*, a group of three venomous setæ, showing the glandular cells (*pc.*) at the base, by which the poison is secreted.

Fig. 3 represents the cells (*sc.*) in the hypodermis which secrete the setæ, and the poison-cells (*pglc*) which secrete the venomous fluid filling the setæ or spines, and which makes them so irritant and annoying when the spines break off from the tubercles bearing them. *A* is a group of setæ arising from a subdorsal tubercle; *cut.*, the cuticle; *hy.*, the hypodermis; *sc.*, the enlarged and specialized cells of the hypodermis which secrete the spines themselves; *pglc*, the nuclei which secrete the venomous fluid which fills the cavity of the seta (*s.*), seen at *p* in a broken spine. *B*, a short entire and a long broken seta; *pglc*, four poison cells; *p.*, the poison in the hollow of the spine.

Fig. 4. Section of a subdorsal tubercle from a larva in Stage I. *sc.*, the setigenous cells, one for each seta; *pglc*, nuclei by which the poison is secreted; *s.*, seta; *p.*, poison in middle of a broken spine; *cut.*, cuticle; *sd. tub.*, spinulated surface of the subdorsal tubercle. Author *del.*

Larva, Stage II.—Length, 3 mm. (Pl. V, Fig. 5). It differs from the previous stage chiefly in the head being nearly covered or overgrown by the hood-like prothoracic segment, so as to be almost as completely covered by it when extended as in the later stages. The short stiff setæ are white instead of brownish at the end; the white hairs are, perhaps, more abundant, and the body is slightly thicker. The second and third thoracic and seventh to ninth pair of abdominal tubercles are now larger than the others. There are now about twelve crotchets on the middle abdominal legs.

It molted July 16–17, hence the length of this stage is 6–7 days.

Fig. 6 represents the seventh abdominal segment of this stage. *d*, the dorsal tubercle, with 12–13 poison-bearing setæ, with brown tips, and five long very finely spinulated hairs, which are about twice as long as the segment is thick; *sd.*, the subdorsal tubercle bearing about twelve venomous setæ, and two or three long spinulated hairs; *sp.*, the spiracle, and directly behind and a little

below it a lateral process (*lp.*); *i.*, the infraspiracular tubercle bearing about eight hairs, but no setæ; *pl.*, the planta; *s.*, the clavate seta.

The hairs are more numerous than before, nearly concealing the body, much as in Stage V.

Stage III.—Length, 5 mm. Of the same color as before, and with no noteworthy change in appearance.

It molted again July 25–26, the length of the stage being about nine days.

Stage IV.—Length, 7–8 mm. The larva only differs from that of the preceding stage in all the hairs being white, and in the woolly or finely spinulated ones being thicker.

It molted August 3, the length of the stage being about 7–8 days.

Stage V.—Length, 9–10 mm. Same as before, but the hairs have grown a little thicker (see Fig. 7, *a*, *b*).

I am uncertain whether the larvæ molted again before the final ecdysis, but Aug. 10–12 they had become 15 mm. long, and were the same as before, but with more long hairs in proportion to the short forked ones. This is perhaps the end of Stage V.

This stage lasted about ten days, as they molted again Aug. 22–23, and some as late as Aug. 30.

Last Stage (*VI*).—Length, of body alone, 20 mm.; but including all the hairs before and behind 30 mm.; breadth of body, 10 mm.

Mature larval characters being acquired only at the last molt, it is now entirely different in shape and color from the preceding stages. The hairs on the anterior third of the body are *slate-gray*, behind *reddish brown*, and they are so dense and fine as to lie upon the body and entirely conceal it; they rise into four longitudinal ridges. The head is not now visible, the head-end is broader than the tail end, with overarching hairs, and a few longer scattered hairs on the front and side of the thoracic segments, and a few long brown hairs on the posterior end; none of these longer hairs are as long as the body is thick, and none of the short barbed stinging hairs are to be seen through the dense pile of simple hairs. (See also Lintner's description, and my own in Report V, *U. S. Ent. Commission on Forest and Shade Tree Insects*, p. 139.)

Unusual Number of Abdominal Legs in the Larva.

In the *American Naturalist* for July, 1885, pp. 714, 715, we

published the following notes in an article entitled "Unusual Number of Legs in the Caterpillar of Lagoa."*

"*Lagoa crispata* Pack. is an interesting moth forming a connecting link between the Dasychiræ (Orgyia) and the Cochlidiæ represented by Limacodes and its allies. As we remarked in our Synopsis of Bombycidæ (1864): 'When we observe the larva we would easily mistake it for a hairy Limacodes larva, for like them the head is retracted, the body is short, and the legs are so rudimentary as to impart a gliding motion to the caterpillar when it moves." After describing the transformations, we added: 'There are seven pairs of abdominal or false legs, which are short and thick. The first pair of thoracic or true legs are much shorter than the two succeeding pairs.'

"Two years ago we found the fully fed caterpillars and also those before the last molt on scrub-oaks in Providence, and again noticed them while walking, then carefully examined them after placing them in alcohol, and again examined the specimens during the past winter. It is well known that caterpillars have no more than five pairs of 'proplegs,' 'false legs' or abdominal feet, as they are variously called; and so far as we have been able to learn, the present caterpillar is the only one which has additional legs, even though rudimentary. As in all lepidopterous larvæ, there are ten abdominal segments. In the larvæ before the last molt there is a pair of rudimentary abdominal legs on the second abdominal segment, forming soft tubercles about one-third as large as the succeeding normal feet; the crown of hooks was wanting, but a tubercle on the anterior side corresponding to a similar one on the normal

* In 1879, or six years before the publication of my note, Dr. H. Burmeister (*Atlas de la description physique de la République Argentine, Lepidoptères*, Buenos Ayres, 1879, pp. xxii, Figs. 6*a*, 6*b*, 6*c*) had described and figured with details, the larva of *Chrysopyga undulata:* "Les six anneaux suivants, du cinquième au dixième, sont pourvus de deux verrues charnues qui représentent les pattes membraneuses ventrales, dont le nombre est de six chez cette chenille, ce qui constitue une exception à la regle générale de la présence de quatre paires de pattes membraneuses sur les anneaux 6 à 9. La première et la dernière de ces six paires de verrues se terminent en avant par un coussin rond aplati, noir, qui ressemble à la plante d'un pied, mais chez les quatres verrues moyennes (6 à 9), il y a un second coussin plus grand, qui ressemble à une véritable patte membraneuse pourvue d'une plante sinueuse et d'une couronne de petits crochets cornés, comme les pattes membraneuses en général (6, c). Le onzième anneau est oblitéré au milieu, ainsi que le quatrième, mais sa présence est bien reconnaissable par les deux portions latérales. Enfin, le douzième anneau est un peu plus grand que les autres et porte la dernière paire de pattes membraneuses, la septième qui est complètement conformée comme les quatres moyennes des six anneaux antérieurs, mais sans la petite plante accessoire de celles ci. Ces dernières pattes sont pourvues seulement de la plante sinueuse garnie de crochets comme les autres.

feet had five or six well-marked stout spines, also two or three scattered ones in the middle, the tubercle being rounded, convex, not flattened at the end.

"On the sixth segment, following the fourth pair of normal abdominal legs, is a pair of tubercles like those on the second segment and exactly corresponding in situation with the normal legs; situated externally are two long straight spines, but none homologous with those forming the crown. At the base in front of each tubercle is a tuft of sparse hairs, and on the outside is a chitinous spot bearing a dense tuft of hairs; these two tufts precisely agree in situation and appearance with those at the base of normal abdominal legs.

"In the fully fed caterpillar the tubercles are exactly the same. It thus appears that in the Lagoa larva the first abdominal segment is footless; the second bears rudimentary feet; segments 3–6 bear normal proplegs; the seventh bears a pair of rudimentary legs; segments 8 and 9 are footless, while the tenth bears the fully developed anal or fifth pair of genuine proplegs.

"While these two pairs of tubercles differ from the normal legs in being much smaller and without a crown of curved spines, they are protruded and actively engaged in locomotion, and in situation, as well as the presence of the basal tufts, are truly homologous with the normal abdominal legs.

"When we turn to the work of Kowalevsky on the embryology of Sphinx, we find that it has ten pairs of abdominal legs which arise in the same manner as the thoracic or chitinous, jointed legs. Of these ten pairs one-half disappear before hatching, leaving the five pairs usually present. It seems to us that the two pairs of rudimentary legs in Lagoa are survivals of these embryonic temporary feet. Although the proplegs are not popularly regarded as true legs, they are undoubtedly so, as embryology proves. In the lower Noctuidæ, such as Catocala, Aletia, etc., the larvæ are at first geometriform, having but three pairs of proplegs; in the geometrids there are but two pairs, while in the Cochlidiæ there are not even any rudimentary feet, thoracic or abdominal. As we have elsewhere observed, the primitive lepidopterous larva must have had a pair of feet on each abdominal segment, and may have descended from Neuroptera-like forms allied to the Panorpidæ as well as Trichoptera."

As this and the case of Chrysopyga are unique, no other lepidop-

terous larva* being known to possess more than five pairs of abdominal legs, when rearing the larva described above we again for the third time carefully and repeatedly observed the caterpillars when alive and watched the movements of the abdominal legs during locomotion, and saw how the two rudimentary pairs, viz., those on the second and seventh abdominal segments, were raised and put down. With the triplet in hand, and allowing the larvæ to walk on the edge of the tin box in which they had been confined, it was easy to see that the above-mentioned proplegs were actively used, performing the same general acts of extension and retraction of the planta as the others, and like them serving to support the body. The first pair, particularly, viz., those on the second abdominal segment, were observed to be nearly as large and long as the normal legs, and to be retracted and then extended, and applied to the surface of the object on which the body was situated, in the same manner as the pair directly behind which have crotchets; and the same was observed as regards the pair on the seventh segment.

(Fig. 7. *a*, dorsal, *b*, lateral view of the larva of *Lagoa crispata*, Stage V; *c*, ventral view of the same to show the seven pairs of abdominal legs; *d*, front part of the same, still more enlarged to show the differences between the first and second pair of abdominal legs, also the under side of the head partly concealed by the prothoracic hood; and the three pairs of thoracic legs; *e*, a side view of the hood, completely concealing the head; *f*, a tubercle with the hairs and spines; *g*, a normal abdominal leg with the crotchets; *g'*, one of the legs on second abdominal segment, without the crotchets; *h*, side view of two abdominal segments showing the spiracle and the lateral glandular process (*lp.*) behind it. Bridgham *del.*)

To further prove to others, who might doubt whether these mobile and extensile processes were really legs at all, I made careful camera sketches of the alcoholic specimens of the freshly hatched larva (Fig. 1), and of one after the first molt (Fig. 5). In Fig. 7 *c*, the first abdominal segment is seen to be completely apodous, but the legs on segments 2 and 7 are seen to have a well-developed extensile planta, though without crotchets, but bearing on the outside a pair of clavate setæ just like those on the other legs. In Stage II (Fig. 5) are seen the same structures; *pl.*, the planta;

* Exception, however, should be made of the larva of Phyllocnistis, and of Nepticula, which possess nine pairs of abdominal legs, which however bear no hooks.

cr., crotchets of the fully developed abdominal legs ; *s.*, the pair of short clavate setæ on the rudimentary legs of the second abdominal segment. It thus appears that these legs are as well developed in the freshly hatched larvæ as in the last stage of larval life.

Their general appearance in the final stage is seen in Fig. 7*c*, which represents the larva enlarged twice as seen from beneath ; at *g* is a normal leg, with the narrow elliptical oval circle of crotchets on the inner and hinder side ; g^1, one of the rudimentary legs without crotchets ; *d*, represents an enlarged view of the head entirely covered above, with the three abdominal segments, and the first, second and third abdominal segments, with the rudimentary leg of the second segment, and the normal legs of the third somite.

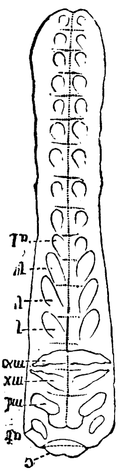


Fig. 8.—Primitive band or germ of a Sphinx moth, with the segments indicated, and their rudimentary appendages. *c*, upper lip; *at*, antennæ; *md*, mandibles; *mx*, *mx'*, first and second maxillæ; *l*, *l'*, *l''*, legs; *al*, abdominal legs.

The occurrence of temporary abdominal legs in the embryos of insects in general is now well known to students of embryology. Kowalevsky was the first to figure what seemed to be such temporary appendages, in the embryo of Sphinx, though he does not refer to these structures in the text of his work. (Fig. 8, which is copied from his work). In subsequent researches by Hatschek on the embryology of *Porthesia chrysorrhœa*, they are neither mentioned in the text nor figured. Tichomiroff, in his work on the development of *Bombyx mori*, appears, however, to have substantiated the truth of Kowalevsky's figures.

Tichomiroff represents in Fig. 26, p. 41, of his work the primitive band of *Bombyx mori*, with the temporary abdominal knob-like appendages developed on abdominal segments 2 to 10 ; they are in a situation homologous with that of the anterior appendages, one on each side of the median line, and within the rudiments of the stigmata of the same segments. Besides they are represented as developed on the ninth and tenth segments, where there are no traces of the stigmata. Owing in part to the rather poor impression of the colored print of the wood-cut, which is inserted in the text, these delicate rudiments are faintly and obscurely printed. In Fig. 27, representing a more advanced stage, it should be observed that the author omitted to letter them ; these rudimentary structures appeared to be still

persistent, though not shown on segment 2, and not as distinct on segments 3 to 5 as before; but on segments 9 and 10 they seem to stand out distinctly from the surface of the segment, though the author did not letter them. In Fig. 28, representing a still more advanced step, there are no traces of these deciduous structures, but the normal abdominal legs (on segments 3–6 and 11) are distinctly drawn and lettered.

Though with some hesitation I yet regarded the figures as representing these deciduous structures, but was unable to read the Russian text.

In his valuable treatise, *Ueber die Polypodie bei Insektenembryonen* (1888), Graber describes and figures the embryo of *Gastropacha quercifolia*, stating that there were no traces of these temporary structures to be seen. He also states that no temporary abdominal legs were found either by Buetschli, or by Grassi, in the honey bee. None have been observed in the Diptera by Weismann and others. Hence it appears, up to this date, that they only occur in the orders below those named above. Graber throws some doubt on Kowalevsky's observations, and states that Tichomiroff also did not discover them. On this account he is led to consider the abdominal appendages of caterpillars as secondary structures.

In his interesting article, "On the Appendages of the First Abdominal Segment of Embryo Insects," Mr. W. W. Wheeler * discusses this question, and gives a list of the species and orders of insects in which these deciduous abdominal appendages have been found. His list shows that in all the Orthoptera which have been studied, pleuropodia, viz., the temporary appendages of the first abdominal segment, and in general those of the succeeding segments, have been observed in the embryos of all the Orthoptera yet examined. In the Hemiptera they have not been observed in three species of Aphis, but have been detected in Cicada and Zaitha. In the Coleoptera they apparently may or may not be present, for example, they have been seen in Hydrophilus, Acilius, Melolontha and Meloë, but not in the chrysomelid genera Lina and Doryphora. The neuropterous genus Sialis and the trichopterous genus Neophylax possess them. He also states that pleuropodia do not occur in the honey-bee embryo studied by Buetschli and by Grassi.

* *Trans. Wisconsin Acad. Sciences*, etc., viii, September 20, 1890.

Graber,* in his last more elaborate and carefully considered work, however, refers more at length to Tichomiroff's memoir on the silk-worm, and quotes from him as follows: "Wood-cut 26 represents the stage in which two new structures become apparent, namely, first, seven pairs of spiracles (from the second to the eighth abdominal segment), and, second, the ventral legs. The last become visible on *all the segments*, except the first. As regards the last ones, I could not satisfy myself that they, as those Kowalevsky refers to in Hydrophilus, arise out of a common germ with the outgrowth bearing the stigmata. This outgrowth arises much later."

He adds further on (p. 42): "*The ventral legs*, which originally appear on all the abdominal segments, with the exception of the first, *exist in their complete number only a short time.* Five pairs of them, namely those which belong to the third, fourth, fifth, sixth and ninth segments, begin to develop rapidly, *while the others very imperceptibly disappear in the mass of the primitive hypodermis*" (*Stammhypodermis*).

On the other hand, in *Bombyx mori*, Selvatico† neither mentions nor figures these deciduous organs. With these facts before him, Graber concludes that the question of the presence or absence of a continuous series of abdominal appendages in view of the extraordinarily short and transitory development of these embryonic structures cannot be answered yes or no, and that the question whether these processes correspond to true appendages, to primary or secondary appendages, cannot in the present state of our knowledge be solved. He then goes on to state that in the embryo of *Bombyx mori* (in all the abdominal segments except the ninth and tenth) *faintly marked knob-like elevations are to be seen which may yet* (*immerhin*) *be considered as the first indications of rudimentary appendages* (see his Fig. 108). He adds that "they are much fainter and are also less sharply defined than those figured by Tichomiroff in wood-cut 26, although on the whole a return to the view of the observer mentioned would be in accord with the truth."‡ In a word, the observations and figures of Graber appear to confirm the text and figure of Tichomiroff, which we therefore

* Vergleichende Studien am Keimstreif der Insecten, von Vitus Graber, Wien, 1890.

† Sullo sviluppo embrionale dei Bombicini. Annuario della r. stazione bacologica di Padova, 1882.

‡ This is a clumsy translation of Graber's rather guarded endorsement of the correctness of Tichomiroff's observations, his expression being: "Obwohl sonst die betreffende Wiedergabe seitens des genannten Forschers der Wirklichkeit sehr nahe kommt."

reproduce (Fig. 9). Graber also goes on to remark: "In general, however, they appear to be completely homotypic (homotop) with the thoracic jointed appendages, and in this respect there could be no reason to call in question their homology with the abdominal appendages of other insects, viz., the Coleoptera and Orthoptera." Finally he concludes that in *Bombyx mori* "the stage of pantopody has only a very ephemeral duration."

In Pieris there are the same relations as in Bombyx, "though the persisting pantopody is more latent." However, he did not perceive any clear traces of the deciduous abdominal legs in Pieris, nor after a reëxamination of his preparations of the primitive streak of Gastropacha did he discover them in that form.

(Fig. 9. Primitive band of *Bombyx mori*, showing the temporary legs on abdominal segments 2–11. After Tichomiroff. *A*. Early stage, in which the abdominal legs al^2–al^{10} appear. *B*. Later stage when they are very faint and all except al^3–al^6 and al^{10} are about to disappear. *C*. The persistent abdominal legs al^3–al^6 and al^{10}, st^2, st^9, the 2d and 3d pair of stigmata.)

As regards the appearance of these structures in the Hymenoptera, Graber states that Buetschli, as is well known, makes the statement that in the primitive streak of the honey bee at a certain stage rudimentary appendages resembling tubercles arise on all the abdominal segments; though Grassi could not confirm this observation.* Very recently, moreover, Carrière reports that in the wall bee† at least on the first two segments, after the appearance of the thoracic legs, "small tubercles" become visible, which however are "only of short duration." In Hylotoma Graber found no traces of these deciduous structures.

From the foregoing facts it would seem reasonable to infer that the figures of Kowalevsky are in the main correct and that the statements and figures of Tichomiroff have been substantiated by Graber. Hence we would feel warranted in concluding that these structures appear in the embryos of certain Lepidoptera and Hymenoptera, though much less distinct and more evanescent than in the lower orders of insects.

If it should be eventually discovered that the deciduous append-

* Balfour, in his *Comparative Embryology*, accepts Buetschli's statements without questioning them (i, 338). See also Buetschli's own statement on p. 537 of his essay: "And after close observation of the following abdominal segments we perceived a very faint similar outgrowth on all of them," etc.

† *Chalicodoma muraria*.

ages are not developed in all Hymenoptera and Lepidoptera, and not at all in the Diptera, this would show that the power of inheritance of these ancestral traits had already in the first two of these orders begun to wane; that their evolution had begun on a higher plane than the polypodous one of the Coleoptera, Orthoptera and ametabolous orders, and that the power was on the verge of extinction. Hence their appearance in certain forms and the cessation of their development in others may be accounted for, just as the scattered and sparse distribution of certain animals, and the reduction in the number of individuals is a preliminary step to their entire extinction.

The lack of these structures in dipterous embryos appears to confirm the view that they are the most extremely modified of all insects. It should be borne in mind that such observations are exceedingly difficult to make, the parts are so delicate and faintly developed, and yet when we take into account the fact that so skillful an observer as Kowalevsky detected them, who was the pioneer in these studies, and who probably had no expectation of discovering such structures, and whose mind was free from any theory in the matter, it seems scarcely probable that he would have figured them unless he had actually seen them.

Returning to the Lepidoptera and to Lagoa, with its rudimentary abdominal legs of the second and seventh segments of the hind body, we feel warranted in the present state of the subject in concluding that they may represent a persistent condition of two pairs of these deciduous abdominal legs. They are certainly of some use to the creature, and thus have survived because they, in a partial way to be sure, have been of service. The others have evidently disappeared from disuse. And it would thus seem that the Lepidoptera and Hymenoptera have descended, like other insects, from polypodous ancestors.

If these conclusions are correct, then Lagoa, in respect to its abdominal legs, even if we do not take into account other characters, is a survivor of an ancient and very generalized type, and represents, as no other known caterpillar, the polypodous ancestor of all Lepidoptera.

The other alternative is that, as Graber once claimed, the abdominal legs of caterpillars are not primitive, but secondary and adaptive structures. Of course these questions can only be settled by further researches. And it is possible that the similar abdominal

legs of larval Tenthredinidæ and the abdominal tubercles of Diptera, which, as in Chironomus and Ephydra, bear hooks, may, instead of being new, adaptive characters, be the homologues of the jointed appendages of the other regions of the body.

After reading Graber's first paper on polypody in insect embryos, and Wheeler's essay, I took it that I should have to abandon the view I expressed in my note in the *American Naturalist* in 1885, and it occurred to me that the seven pairs of lateral processes on the first seven segments of Lagoa might be so many pairs of pleurópodia. These processes we may now consider.

THE EXTERNAL LATERAL ABDOMINAL GLANDULAR PROCESSES OF LAGOA.

These are present at birth and in all the larval stages and are represented by Figs. 10 to 13, also Figs. 1 and 5.

There are seven pairs of them, a pair to each of the first seven abdominal segments. They are situated near to and directly behind, but a little lower down than the spiracles and above the infraspiracular tubercles. In fact, they occupy the exact position of the evaginable glands of *Hyperchiria io* and *Hemileuca maia*, etc. In shape they are elongated pyriform conical, or digitiform, being slightly contracted at the base, and with two slight contractions towards the free end, and they remind one of the shape of the appendages of insect embryos just when the joints are beginning to appear. The free end is conical, rounded and, so far as I have been able to discover, imperforate. They are not capable of being retracted and appear to be permanently evaginate, since each pair along the side of the abdomen is of the same general length and size, none being wholly or in part retracted.

Fig. 10. *A*, a camera drawing, represents the shape in the third stage, just before molting; *sp.*, spiracle; the process was on the point of being molted and is hollow. *B* represents the process just after evagination, belonging to Stage IV. It is a little longer and larger than before (both figures are drawn to the same scale, × one half inch *A* eyepiece) and filled with granules in the middle, with narrow linear cells (*hy ?*) on the outside or cortex which remind one of the linear cells in the pleuropodia of Blatta figured by Wheeler (Pl. i, Figs. 3, 4). It is to be observed that the spiracle in this stage ($sp.^1$) is nearly twice as large as in Stage III (*A. sp.*).

In the later stages these processes are concealed by the hairs. They are invariably pale, whitish, the cuticle is smooth and naked, not bearing any setæ or hairs, differing in this respect from the fleshy digitiform processes or soft tubercles of the larva of Attacus and of certain Papilionidæ.

To examine the structure of these processes transverse sections of the larvæ of Stage I were made, and also blocks of the integument of the full-fed larva bearing two of the processes were cut with the microtome. Fig. 11 represents a transverse section of the body of the larva before the first molt, involving the lateral grandular processes on each side of an abdominal segment; *int.*, intestine, with the epithelial or mucous layer enclosing vacuoles, and *m.*, the outer or muscular layer; *mp.*, section of four of the Malphigian or urinary tubes; *n.g.*, the ganglia; *ht.*, the heart; *f.*, cells of the fatty body; *sc.*, thickened portion of the hypodermis (*hy.*) lying under the tubercles and modified into the setigenous cells; *l.*, the abdominal legs; *m.*, muscles; m^1., a pair of muscles inserted near the base of the lateral glandular processes; *cut.*, cuticle. The lateral grandular processes (*l g p*) are seen to be inserted a little below the middle of the segment, and that they are permanently evaginated is seen by the nature of the cuticle, which is rough and subspinulated on the basal third. The process is filled with elongated gland-cells.

Fig. 12. represents different sections, 1^a–1^d through the process of one segment, and 2, 2^a, 2^b through another, the lettering as before.

Longitudinal (A, B, C) and a transverse section (D) through these processes in the fully fed larva are represented by Fig. 13. At A the lumen (*l*) is a deep narrow cavity, with the secretion (*secr.*) collected at the mouth of the cavity composed of a thin mucous-like coagulated fluid, containing granules of varying degrees of fineness which take the stain readily. Outside of these are collected fine *nuclei* (*b*, *c*), stained dark and enveloped in a slight transparent pale protoplasmic envelope, which may be blood-corpuscles. The glandular cells themselves are simply modified hypodermal cells, as seen at *C;* those at the free end of the process are very much elongated, the nucleus however situated near the periphery of the process. In some of the nuclei, indistinct nucleoli are seen, and deeply stained granules, especially around the periphery of the nuclei. The specimens had been in

alcohol for at least three years, so that the exact histological structure of the nuclei could not be clearly brought out, but in the general appearance of these grandular cells, there is a general and suggestive resemblance to those filling the pleuropodia, figured and described by Wm. M. Wheeler.* At *B* is represented a section on one side of the middle, but still showing the spacious lumen. In the section represented by *C* the knife passed through the process still nearer the outer edge and near the base; at C^1 three of the glandular cells with their large deeply stained nuclei are drawn. A transverse section at *D* shows the large lumen or cavity (*l*) (in all the preparations the hypodermis and other cellular tissues have shrunk and separated widely from the cuticle).

As to the function and homologies of these structures it is difficult to decide. I have never noticed that they give off any odor, though they may prove to be repugnatorial; they are not visible in the living insect, being concealed by the long dense hairs clothing the body; they are not spraying organs as they are imperforate at the end, not ending as the lateral eversible glands of *Hyperchiria io*, etc., in a crateriform orifice.

There are three views which might be taken as to their homologies.

1. They may be merely fleshy papillæ like the short or long tubercles of the larvæ of Attacinæ and of certain Papilionidæ.

2. They may be permanently everted glands, or osmateria, which have by disuse lost their power of retraction, and their crateriform opening, as well as the power of secreting a malodorous fluid.

3. If it should ultimately be fully proved that Lepidoptera have temporary abdominal appendages, and that the proplegs or so-called abdominal legs, with crotchets, are merely secondary, adaptive structures, then these may be pleuropodia, or homologues of the temporary embryonic abdominal legs of the lower insects.

The first view is unlikely because in the larva of Attacus each lateral long horn-like process arises *in front* of the spiracle, on the prothoracic and second abdominal segments, and there are no such processes in a corresponding position on the other abdominal segments. Moreover the elongated fleshy or soft, flexi-

* Appendages of the first abdominal segment, etc., 1890.

ble tubercles in the larvæ in question are of the same color as the skin and are armed with fine hairs or setæ.

The third view is one which is incapable at present of proof, so that we are driven to provisionally regard these processes as persistently evaginate repugnatorial, or at least scent glands or osmateria which have possibly lost their power of ejecting a poisonous or disagreeable spray or fluid, owing to the fact that by a change or transfer of function the spine-like setæ are poisonous, thus functionally replacing a set of organs originally actively repugnatorial.

It is also to be observed that the fact that in the Hemileucidæ these eversible glands are restricted to but two of the abdominal segments, shows that in the ancestral forms these structures may have been developed on all, or at least nearly all the abdominal segments.

LAGOA, AS REGARDS ITS LARVAL, PUPAL AND IMAGINAL CHARACTERS, A GENERALIZED TYPE.

We have already seen that in respect to its general appearance the larva of Lagoa is in some respects intermediate between the Cochliopodidæ and Liparidæ. It resembles the former group in the short thick body; in the head being concealed by the prothoracic hood, and in the venomous spines.

On the other hand it resembles the Liparidæ in the hairy body, the hairs being finely plumose, a peculiarity of more common occurrence in the Liparidæ than in the Cochliopodidæ.

As regards the cocoon, this is intermediate in form and texture between that of Orgyia, etc., and the Cochliopodidæ, but it more closely approaches that of the latter; it varies somewhat in density in different species, being usually quite firm and dense like parchment, nearly as much so as in those of the Cochliopodids, and also approaching them in shape, being oblong-cylindrical, oval, contracted at the anterior end, and with a separately spun lid, closing the anterior end. As Dr. Lintner has shown with many interesting details: "The lid is woven by the caterpillar separately from the rest of the cocoon, and is not a section cut from it after its completion" (p. 142).

The pupa is much like that of Limacodes, etc., the integument or cast cuticle being remarkably thin, and after the exit of the moth the antennæ and legs, as well as the wings, are free from the body;

while the latter is split both down the back and along the under side to the end of the thorax. Moreover when the moth escapes from the pupa-skin, the latter is left with the head and thorax projecting out of the end of the cocoon.

As regards its imaginal or adult characters it is also intermediate between the two families mentioned. In the short stout body and short broad wings it has the habit of a Limacodes, rather than of such Liparid genera as *Porthesia*, etc.

In the shape of the antennæ and palpi it is about as near the Liparidæ as the Cochliopodidæ.

In respect to the denuded head, Lagoa is much more like Euclea than the Liparidæ. The clypeus is rather long and narrow, similar in shape to that of Euclea, though rather narrower, and is thus more like that of the Cochliopodidæ than that of the Liparidæ, represented by Orgyia and the European *Porthesia chrysorrhœa,* whose denuded heads I have examined. The epicranium and occiput taken together (on the median line of the body) are about one-third as long as the entire clypeus.

As regards the venation, Lagoa is decidedly nearer Euclea and other Cochliopodids than the Liparidæ (I have examined the venation of Orgyia and Parorgyia). Lagoa has the same wide costal region of the fore wings as in Euclea, that of the Liparidæ being very narrow; the five branches of the subcostal vein are thrown off in nearly the same manner as those of Euclea and Limacodes. The discal veins and origin of the independent (sixth subcostal) are almost precisely as in Euclea, and the four branches of the median vein are also similar in their mode of origin, and unlike those of Orgyia and Parorgyia.

In the hind wings, as in the Cochliopodidæ, there are ten veins, in the Liparidæ only nine; there are but two branches of the subcostal vein; the third branch being detached, so that there are two independent veins, one arising from the anterior, and the other from the posterior discal vein. In the Liparidæ mentioned there is no independent vein at all. The four median veinlets have the same peculiarities in their mode of origin as in Cochliopodids and the same differences from the Liparidæ.

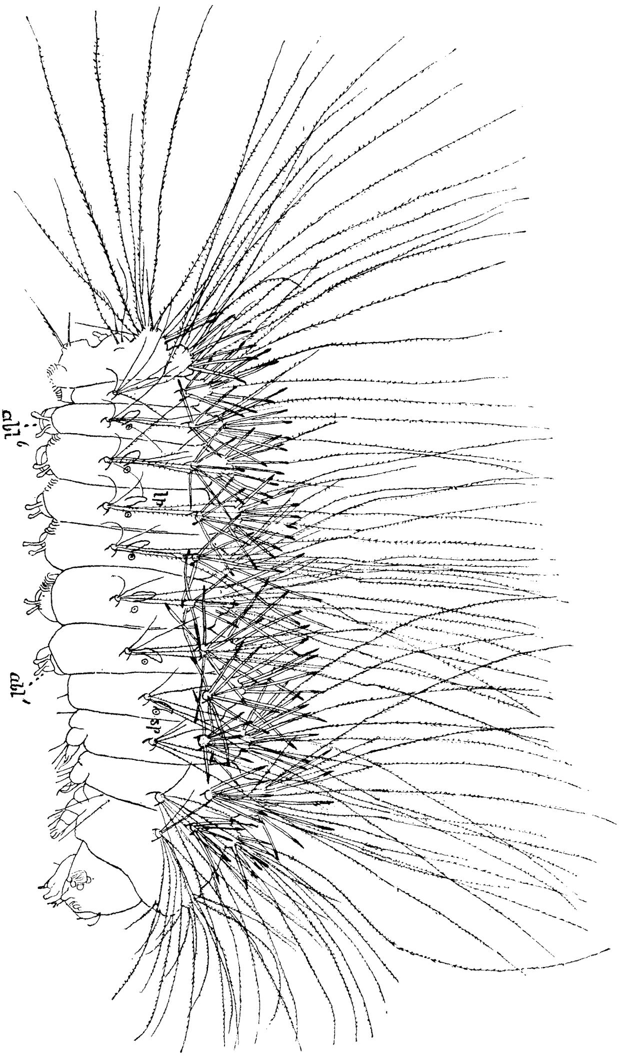
To sum up: in the superficial characters, of the imago, and in having in the larva abdominal legs, Lagoa resembles the Liparidæ, but in all its essential characters, those of the egg, larva, pupa and imago, it belongs with the Cochliopodidæ, except in the matter of

the presence of abdominal legs in the larva. On this account it seems fairly entitled to be regarded as the type of an independent group. We may either regard it as a generalized, ancient group of Cochliopodidæ, and refer it to a subfamily *Lagoinæ*, or we may boldly remove it altogether from either of the two families mentioned and consider the genus as the representative of a distinct family and designate the group by the name of *Lagoidæ*. This on the whole seems to us to be perhaps the most judicious course to pursue. At all events the insect is plainly enough an ancient, ancestral, or generalized form. It is, so to speak, a primitive Cochliopodid with larval abdominal legs. It lays eggs like those of Limacodes, etc.; its head in the larval state is concealed from above by the prothoracic hood; its larval armature is more of the Cochliopodid type than Liparid; so are the pupal characters and the nature of the cocoon; and the shape of the important parts of the head and the essential features of the venation are overwhelmingly Cochliopodid. Under these circumstances we feel justified in regarding Lagoa as a most interesting ancestral form, and as affording arguments for considering the Bombyces as a whole as a generalized and ancestral group, and epitomizing the other higher Lepidopterous families somewhat as Marsupials do the placental orders of mammals.

The genus is peculiar to North and South America, and may rank with such forms as the colossal sloths, and certain American vertebrate survivors of middle Tertiary times. In some respects it is intermediate between the Saturniidæ, especially the higher Attacinæ, and the Cochliopodidæ; its clypeus, and the larva, approach in some respects those of the Attacinæ.

[NOTE. I find since this paper was read to the Society that, according to Berg (*Miscellanea Lepidopterologica*, 1883), Megalopyge of Hübner preoccupies Lagoa. Berg also founded the family *Megalopygidæ*, of which Lagoidæ is a synonym.]

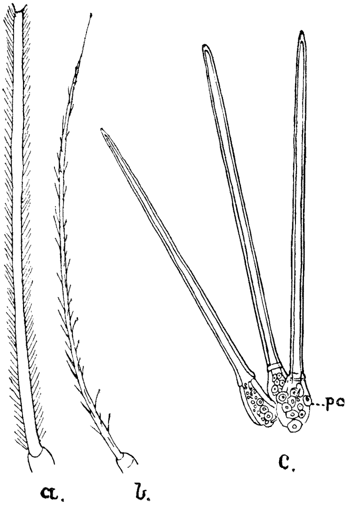
Packard del.



1.

Larva of Lagoa crispata, Stage I, much enlarged.

Plate I (Packard).



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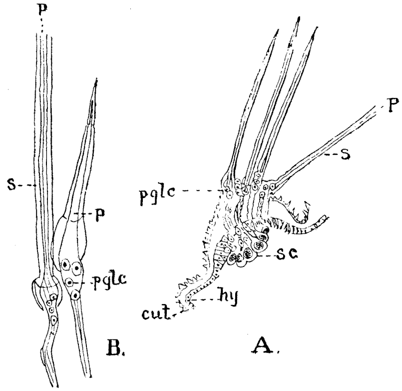

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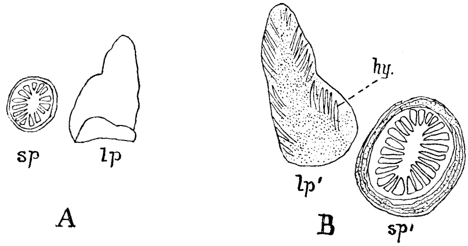

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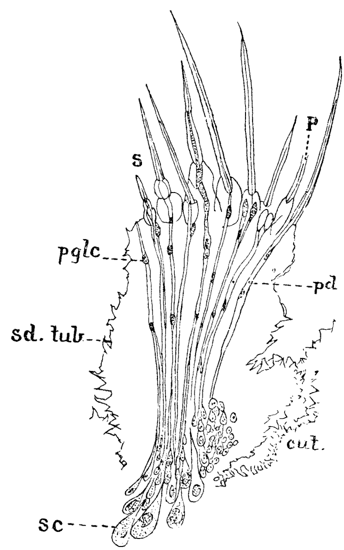

4.

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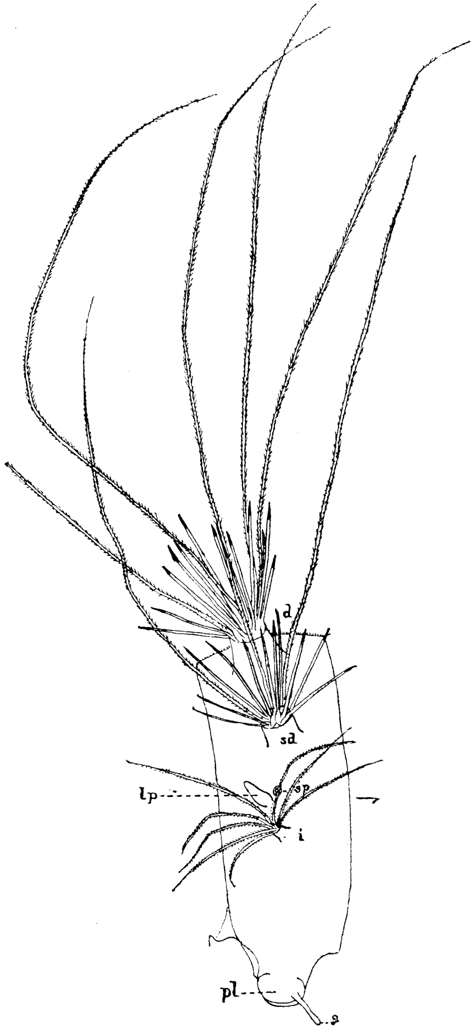
Armature, etc., of Lagoa.

Plate II (Packard).



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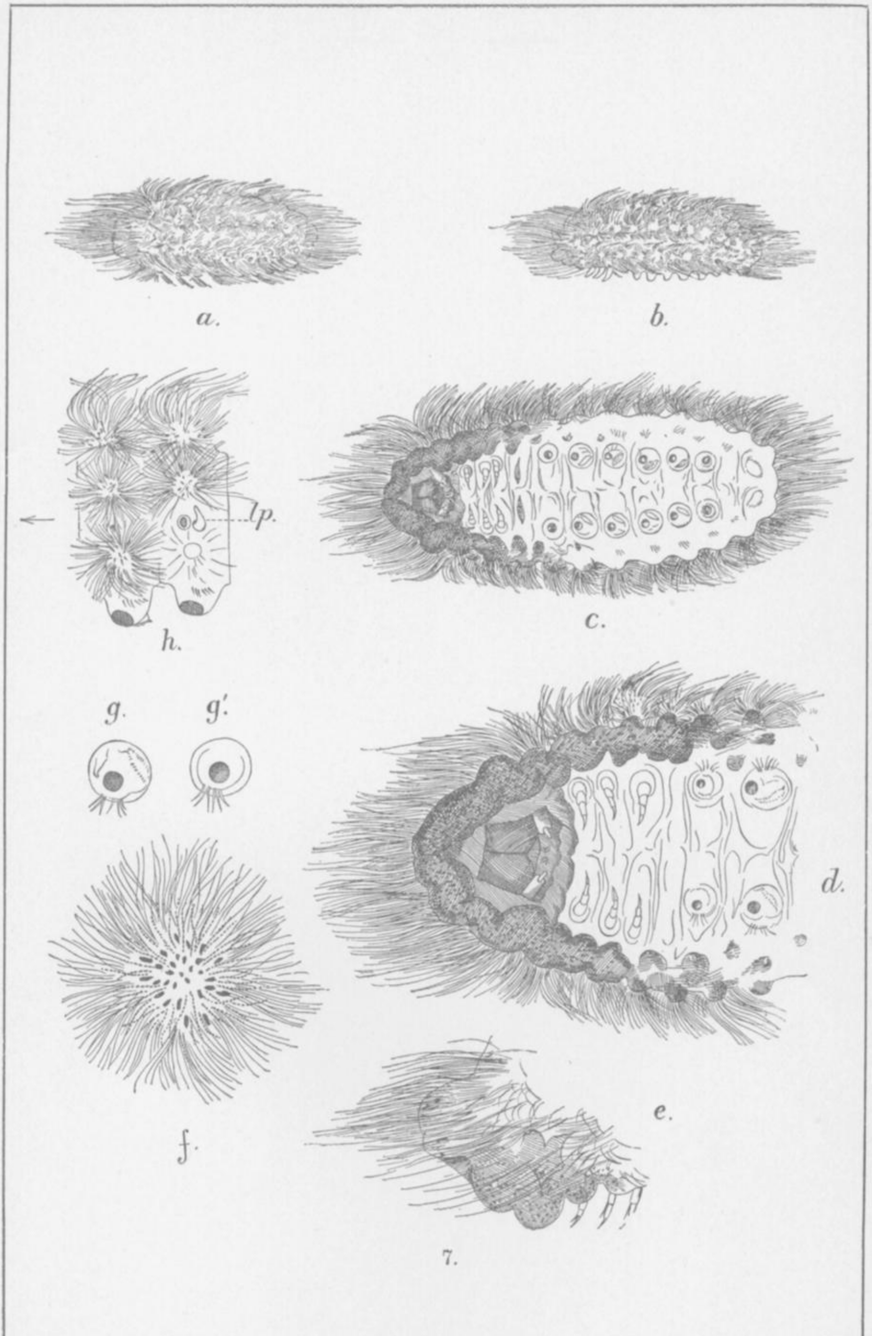
View from Side of Seventh Abdominal Segment of Lagoa, Stage II.

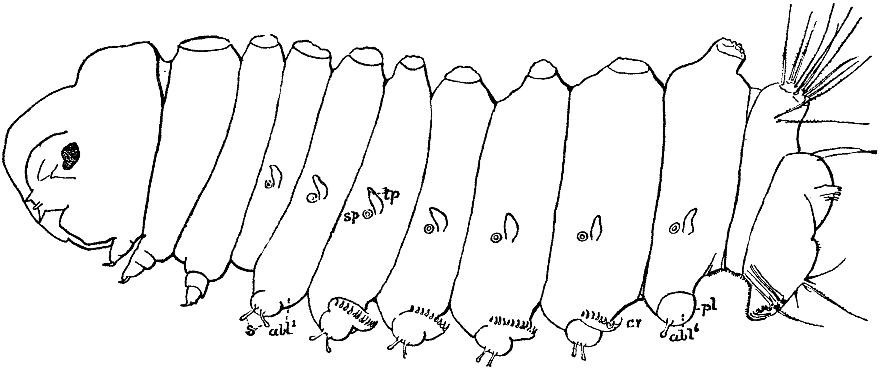
Plate III (Packard).



J. Bridgham del.

Later Larval Stages of Lagoa crispata.

Plate IV (Packard).



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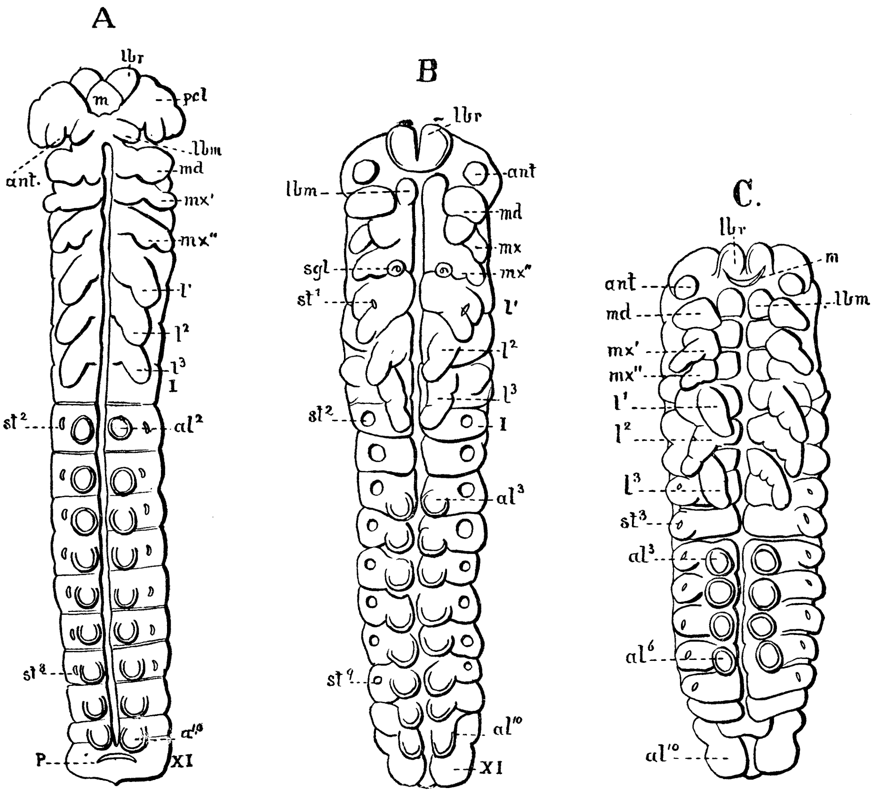

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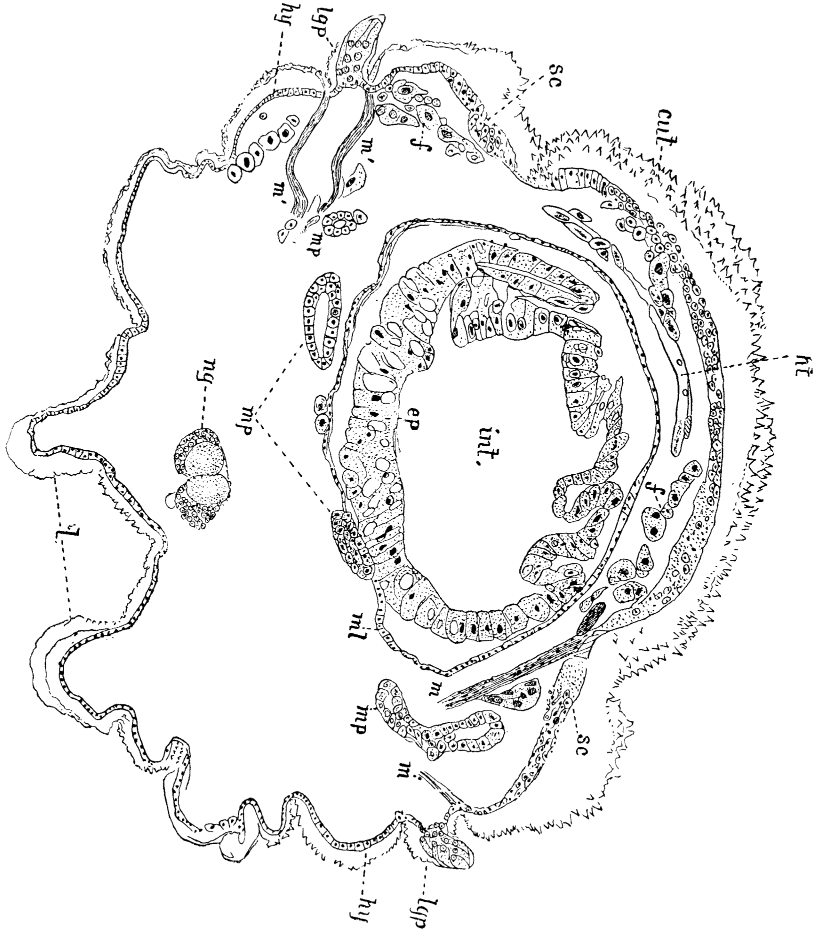
Larva, Stage II, and Embryo of Bombyx mori.

Plate V (Packard).

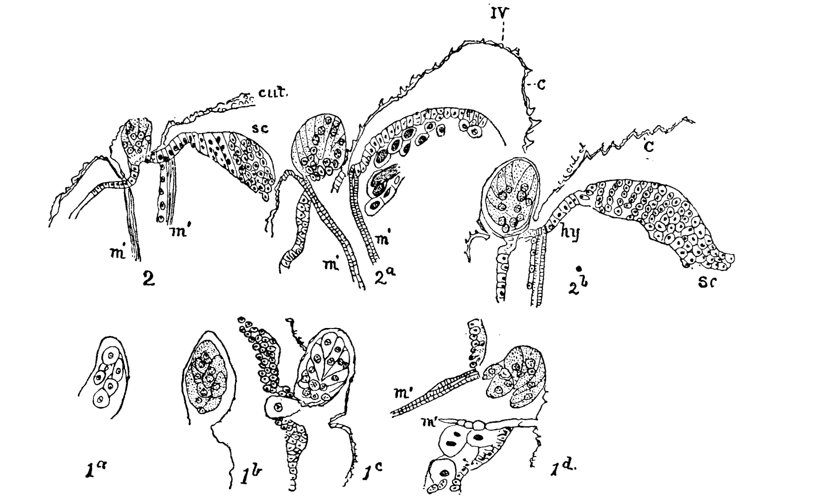
Section through an Abdominal Segment of a Larva of Lagoa in Stage I.



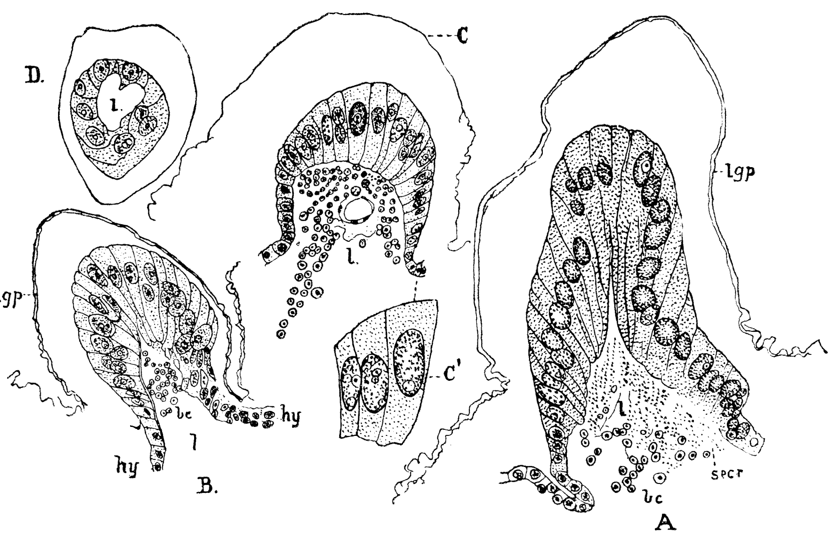
11.

(*Packard del.*)

Plate VI (Packard).



12.



13.

(*Packard del.*)

Sections through the lateral Glandular Processes of Lagoa.

Plate VII (Packard).